THE EFFECTS OF DECOUPLING ON LAND ALLOCATION

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Abstract

The purpose of this article is to study the impact of agricultural policy decoupling on land allocation decisions. Our analysis contributes to the literature by formally assessing the effects of decoupling on farms' crop mix and on the decision to set land aside. The analysis is undertaken within the framework of the model of production under uncertainty developed by Just and Zilberman (1986). Our empirical application focuses on a sample of Kansas farms observed from 1998 to 2001. Results show that US agricultural policy decoupling could have involved a shift in land use away from program crops towards non-program commodities offering higher expected profits and idle land.

Keywords: risk, risk preferences, land allocation

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The purpose of this article is to study the impact of agricultural policy decoupling on land allocation decisions. Our analysis contributes to the literature by formally assessing the effects of decoupling on farms' crop mix and on the decision to set land aside. The analysis is undertaken within the framework of the model of production under uncertainty developed by Just and Zilberman (1986). Our empirical application focuses on a sample of Kansas farms observed from 1998 to 2001. Results show that US agricultural policy decoupling could have involved a shift in land use away from program crops towards non-program commodities offering higher expected profits and idle land.

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I. INTRODUCTION

Until recently, the design of domestic agricultural policies in developed countries has given priority to methods that guarantee a price floor for agricultural commodities. Price support mechanisms can range from supply restrictions imposed on the domestic market, price subsidies, or public purchases of agricultural commodities to offset excess supply. A wide literature has shown that price support mechanisms may intensify production practices and bring about significant deadweight losses (Gardner, 1992). The unfavourable consequences of agricultural protectionism became widely recognized by the 1980s. It became clear that agricultural intervention based on price guarantees and other market insulating policies led to overproduction, which in turn brought about market distortions and disagreements in multilateral trade policy negotiations. Recognition of these problems motivated multilateral and/or bilateral trade agreements that advocated for agricultural protectionism dismantling processes. In the framework of these agreements, different countries have reformed their domestic agricultural policies. Economic theory views lump sum transfers as the most efficient method to redistribute income among individuals (Williamson, 1996). The trade-off between political pressures for continued support to farmers and the policymakers' will to reduce efficiency losses resulted in an increased use of decoupled agricultural policies. Decoupling is a term used to designate the break of the link between subsidies and production. Price supports are usually replaced by lump sum income transfers that do not depend on actual production or prices.

The conventional approach to the analysis of the effects of agricultural policies on farmers' profit maximization decisions has been to assume perfect markets (including credit markets), risk neutral producers and constant returns to scale. Under these assumptions, the literature has shown that the impacts of decoupled policies on production decisions are limited. However, if economic agents are not risk neutral, markets are imperfect, or returns to scale are other than constant, apparently decoupled payments could have more implications (see Phimister, 1995; Hennessy, 1998; or Rude, 2001). A number of studies that have assessed economic agents' risk preferences have found evidence in favour of risk aversion (see, for example, Hansen and Singleton, 1983; Chavas and Pope, 1985; Pope and Just, 1991). If uncertainty and risk preferences are introduced in the analysis of the impacts of decoupling, results suggest that apparently decoupled policies can influence production decisions (Hennessy, 1998; Sandmo, 1971). It is thus very important to account for risk and risk preferences when assessing the effects of decoupling.

When coupled or partially coupled, income supports often involve restrictive supply management rules that limit farmers' capacity to respond to market conditions. For example, eligibility for public subsidies is usually made conditional upon producing specific crops, the program crops. In this regard, decoupling involves increased planting flexibility in that direct payments are not tied to the production of certain commodities. Farmers being allowed more planting flexibility are likely to be more responsive to market conditions and alter their crop mix accordingly. To the extent that planting flexibility includes the possibility of agricultural land idling, farmers will also consider setting land aside when taking their decisions on land allocation.

There are yet other mechanisms through which the decoupling of agricultural policies can influence land allocation decisions. These mechanisms are the changes in relative market prices and farmers' risk attitudes. The reduction in price supports is likely to make program crops less attractive relative to non-program commodities and land idling. Also, to the extent that farmers' risk preferences are influenced by wealth (Sandmo, 1971; Just and Pope, 1978; Hennessy, 1998; Just and Zilberman, 1986) and to the extent that decoupled payments and price changes have the potential to affect the wealth of participant farmers, their willingness to assume risk may be altered. Because risk is a fundamental component of agricultural production and because yield variability can differ by crop type, government transfers might affect farms' land use by means of altering farmers' risk attitudes.

Decoupled agricultural payments were introduced in the United States (US) with the 1996 Federal Agricultural Improvement and Reform (FAIR) Act, which involved a substantial change in the way income support was provided to farmers. With the FAIR Act, market price supports and deficiency payments were being partially replaced by Production Flexibility Contract (PFC) Payments whose amount and entitlement would not depend on actual production or prices, and a deficiency payment program that guaranteed a minimum support price for program crops including soybeans. While under the 1990 Act and with the exception of the flex acres, producers were required to plant the base acreage to the base crop in order to be eligible for deficiency payments, entitlement to receive PFC was based on qualified acres historically enrolled in commodity programs, allowing land to be put to any agricultural use, including the production of any crop with the exception of fruits and vegetables (unless it was used in this way in the past), or idled.

The purpose of this article is to study the impacts of decoupling on land allocation decisions. Our analysis contributes to the literature by formally assessing the effects of decoupling on farms' crop mix and on the decision to set land aside. The analysis is undertaken within the framework of the model of production under uncertainty developed by Just and Zilberman (1986). We extend this model to study supply responses to decoupled payments and to include set aside among land use alternatives. Though various analyses have addressed the effects of decoupling on producers' decisions, no existing research has studied the impacts of decoupled payments on farms' land allocation using the extended Just and Zilberman (1986) model. Our empirical application focuses on a sample of Kansas farms observed from 1998 to 2001. Results suggest that US agricultural policy decoupling could have involved a shift in land use away from program crops towards non-program commodities offering higher expected profits and idle land.

II. CONCEPTUAL FRAMEWORK

The objective of our model is to assess the effects of decoupling on farm land allocation. We adopt Just and Zilberman (1986) model of production under uncertainty. Because agricultural producers are not likely to be neutral to risk, farmers' risk preferences are explicitly considered. Our model defines risk preferences as a function of wealth (Just and Zilberman, 1986; Pope and Just, 1991; Hennessy, 1998). If economic agents are risk averse and their risk adversity decreases with wealth (Pope and Just, 1991; Bar-Shira, Just and Zilberman, 1997), an increase in decoupled payments is expected to alter the crop mix towards more risky crops that offer higher expected margins. The reduction in price supports for program crops that characterizes a decoupling process will reduce the attractiveness of these crops in favour of non-program commodities and/or idle land. Apart from the substitution effects, a change in output prices will also have an income effect that, under the assumption of decreasing absolute risk aversion (DARA) preferences, is likely to increase risk adversity.

The 1996 FAIR Act involved the introduction of decoupled payments that allowed, with some restrictions, full planting flexibility. We extend Just and Zilberman (1986) model to allow for these payments and the possibility to receive them even if agricultural land is left idle. Our model offers an improved picture of farmers' behaviour by allowing to optimize land allocation in response to policy. We model PFC payments as simple lump sum transfers, thus recognizing that under the new scenario farmers will manage their crop mix in accordance with market conditions.

Consider a firm that produces two outputs, crop 1 and crop 2. Crop 1 represents a program crop in that eligibility for government payments under the old policy regime required crop acres be planted to this crop. Crop 2 is a non-program crop. Yields per acre are defined as uncertain variables and expressed as $\mathbf{Y} = (y_1, y_2)$. For simplicity, it is assumed that producer uncertainty derives only from production, but not from market conditions. If additive production risk is assumed, the production function of crop i can be expressed as $y_i = y_i(x_i) + \varepsilon_i$, where x_i is the per acre quantity of a variable input x allocated to the production of crop i, and ε_i is a stochastic error term with mean $E[\varepsilon_i]=0$ and variance $\operatorname{var}[\varepsilon_i]=\sigma_i^2$. The first two moments of the joint distribution of yields are denoted by $E\begin{bmatrix} y_1 \\ y_2 \end{bmatrix}=\begin{bmatrix} \bar{y}_1 \\ \bar{y}_2 \end{bmatrix}$ and $\operatorname{cov}\begin{bmatrix} y_1 \\ y_2 \end{bmatrix}=\begin{bmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{bmatrix}$, where ρ represents the correlation coefficient among the two crop yields. The quasi rents derived from crop i are expressed on a per acre basis as $\Pi_i = p_i y_i - w x_i$, being the first two moments of the joint distribution of quasi rents $E\begin{bmatrix} \Pi_1 \\ \Pi_2 \end{bmatrix}=\begin{bmatrix} \bar{\Pi}_1 \\ \bar{\Pi}_2 \end{bmatrix}$ and $\operatorname{cov}\begin{bmatrix} \Pi_1 \\ \Pi_2 \end{bmatrix}=\begin{bmatrix} \varpi_1^2 & \rho\varpi_1\varpi_2 \\ \rho\varpi_1\varpi_2 & \varpi_2^2 \end{bmatrix}$, where $\varpi_i = p_i\sigma_i$.

Total crop land (A)[1] is allocated to the production of the two crops considered or left idle yielding the following vector of land allocation: $\mathbf{A}=(A_1, A_2, A_3)$, where $A = A_1 + A_2 + A_3$, A_3 represents idle land and A_1 and A_2 symbolize land allocated to program and non-program crops respectively. The problem of land allocation can alternatively be expressed in proportions as $\mathbf{L}=(L_1, L_2, L_3)$, where $L_i = \frac{A_i}{A}$ and $L_1 + L_2 + L_3 = 1$.

It is assumed that farmers take their decisions with the aim of maximizing the expected utility of their wealth $\max\limits_{L_1,L_2,L_3,x_1,x_2} E[u(W)] = \max\limits_{L_1,L_3,x_1,x_2} E\left[u\left(W_0 + G + \Pi_1 A L_1 + \Pi_2 A(1-L_1-L_3)\right)\right]$, where W represents farms' total wealth, W_0 stands for farms' initial wealth, and G are decoupled income-support

[1] Because for our sample of farms crop land remained almost constant during the period of analysis, A is assumed to be fixed.

payments. The quasi rent associated to idle land is assumed to be equal to zero. Following previous literature, we assume risk neutrality in the input decision[2] which leads to independence of land allocation from variable input decisions (Just and Zilberman, 1986). Under this assumption the first order conditions of the land allocation problem can be expressed as:

$$\frac{\partial E[u]}{\partial L_1} = E\left[\frac{\partial u}{\partial W}\left(\Pi_1 - \Pi_2\right)\right] \geq 0 \tag{1.1}$$

$$\frac{\partial E[u]}{\partial L_3} = E\left[\frac{\partial u}{\partial W}\left(-\Pi_2\right)\right] \geq 0 \tag{1.2}$$

By approximating the marginal utility around the expected wealth $\left(\bar{W} = W_0 + G + \bar{\Pi}_1 A L_1 + \bar{\Pi}_2 A(1 - L_1 - L_3)\right)$ through a second-order Taylor series expansion, the first order conditions can be alternatively expressed as:

$$\frac{\left(\bar{\Pi}_1 - \bar{\Pi}_2\right)}{A} - R\left\{L_1 \nu_1 + (1 - L_3)\nu_2\right\} \geq 0 \tag{2.1}$$

$$\frac{-\bar{\Pi}_2}{A} - R\left\{L_1(-\nu_2) + (1 - L_3)\nu_3\right\} \geq 0 \tag{2.2}$$

[2] As Just and Zilberman note, the assumption of risk neutrality is very common in models with stochastic production and is necessary for the dual cost and production functions to be independent of risk preferences. This assumption allows to derive a theoretical framework that is more tractable at the empirical level.

where $R = R(\bar{W}) = -\left(\frac{\partial^2 u}{\partial \bar{W}^2}\right)\left(\frac{\partial u}{\partial \bar{W}}\right)^{-1}$ represents the Arrow-Pratt coefficient of absolute risk aversion. Following Bar-Shira, Just and Zilberman (1997) we assume R is a function of farms' expected wealth that can be represented by $R = \eta \bar{W}^{\beta}$, where η and β are parameters. This is a flexible specification in that it does not restrict the specific type of farmers' risk preferences. Risk adverse (neutral) [seeking] attitudes are represented by $\eta > (=)[<]0$. We assume farmers to be risk-averse ($\eta > 0$). The wealth elasticity of absolute risk aversion corresponds to β. If farmers have decreasing (constant) [increasing] absolute risk aversion preferences, $\beta > (=)[<]0$. In accord with previous studies (Bar-Shira, Just and Zilberman, 1997; Isik and Khanna, 2003) we assume here that farmers have DARA preferences ($\beta < 0$). Expression $v_1 = \varpi_1^2 - 2\rho\varpi_1\varpi_2 + \varpi_2^2$ $= \mathrm{var}\left(\frac{\partial \bar{\Pi}_T}{\partial L_1}\right) > 0$ is the variance of the marginal profit derived from increasing land allocated to crop $i = 1$ and $\bar{\Pi}_T = L_1\Pi_1 + (1 - L_1 - L_3)\Pi_2$. The result of multiplying $v_2 = \rho\varpi_1\varpi_2 - \varpi_2^2$ by $(1 - L_3)$ is $\frac{1}{2}\frac{\partial \,\mathrm{var}\,\Pi_T}{\partial L_1}$, which represents one-half the marginal variance of profit when $L_1 = 0$, i.e. at zero capacity allocation. Finally, $v_3 = -\varpi_2^2$ corresponds to the negative value of the variance of non-program crop quasi rents. Note that expressions (2.1) and (2.2) above involve the equalization of the marginal mean income effect derived from an increase in land allocated to crop i and the marginal risk effect discounted to a certainty equivalent by using the Arrow-Pratt coefficient of absolute risk aversion.

In order to determine the effects of decoupling on land allocation decisions, we use comparative statics. The consideration of a multi-product land allocation problem involves substantial complexity relative to a more simplified two-product model and yields comparative statics formulae that cannot be signed. In order to make comparative statics more simple, but also more clear, we simplify the model to a consideration of only two alternatives in the land allocation problem: L_1 and L_i, $i = 2,3$.[3] It is important to note that model simplification is only limited to the comparative statics analysis in this section, and that the empirical implementation will be based upon the generalized three-product model.

Let's consider a land allocation problem that only includes program and non-program commodities. In such scenario the system of first-order conditions is reduced to:

$$\frac{\left(\bar{\Pi}_1 - \bar{\Pi}_2\right)}{A} - R\left\{L_1 v_1 + v_2\right\} = 0 \tag{3}$$

where $v_1 = \mathrm{var}\left(\frac{\partial \bar{\Pi}_T}{\partial L_1}\right)$, $v_2 = \frac{1}{2}\frac{\partial \,\mathrm{var}\,\Pi_T}{\partial L_1}$, and $\bar{\Pi}_T = L_1\Pi_1 + (1-L_1)\Pi_2$. As explained above, in a decoupling process lump sum payments are usually introduced to replace price supports. Our comparative statics analysis thus focuses on determining the sensitivity of the crop mix to changes to program

[3] Note that this simplification is economically reasonable as it represents two possible corner solutions that can apply to our problem, i.e. that farmers decide not to set land aside or diversify the crop mix.

crop prices and to lump sum payments. The comparative statics results can be summarized in the following propositions (proofs are presented in the appendix).

PROPOSITION1. *Land allocated to the program crop (* $i=1$ *) increases with an increase in decoupled payments (* G *) if* $\rho > \frac{\varpi_2}{\varpi_1}$*, or if* $-\infty < \rho < \frac{\varpi_2}{\varpi_1}$ *and* $|L_1 \nu_1| > |\nu_2|$. *On the other hand, land allocated to the program crop decreases with an increase in* G *if* $-\infty < \rho < \frac{\varpi_2}{\varpi_1}$ *and* $|L_1 \nu_1| < |\nu_2|$.

Proposition 1 can be economically interpreted as follows. An increase in decoupled payments improves farmers' wealth which in turn increases their willingness to assume more risk. This could reduce the attractiveness of crop mix diversification as a strategy to manage farm income risk. This will only be pursued if yields correlation is negative or takes low positive values, and if an increase in program crop production would substantially reduce the profit (Π_T) variance. Otherwise diversification will not be pursued.

PROPOSITION 2. *For a negative value of the mean effect of production, land allocated to the program crop decreases with an increase in* p_1 *if* $\rho < 0$ *and* $\left| L_1 \frac{\partial \nu_1}{\partial p_1} \right| > \left| \frac{\partial \nu_2}{\partial p_1} \right|$, *if* $0 < \rho < \frac{\varpi_1}{\varpi_2}$*, or if* $\rho > \frac{\varpi_1}{\varpi_2}$ *and* $\left| L_1 \frac{\partial \nu_1}{\partial p_1} \right| < \left| \frac{\partial \nu_2}{\partial p_1} \right|$. *Otherwise, land allocated to crop 1 only decreases if the mean effect outweighs the risk effect.*

The economic meaning of proposition 2 can be expressed as follows. If the expected mean effect of production is negative, an increase in p_1 only motivates an increase in L_1 if this increase involves some gains in terms of risk management that outweigh the negative mean effect. If yields are negatively correlated, the gains in terms of risk management require a substantial reduction in the marginal variance of profit. However, if yields are highly and positively correlated (and thus diversification towards L_2 is less attractive) a small increase in the marginal variance is tolerated, as long as the risk effect is of bigger magnitude than the mean effect.

PROPOSITION 3. *For a positive value of the mean effect of production, land allocated to the program crop increases with an increase in* p_1 *if* $\rho < 0$ *and* $\left| L_1 \frac{\partial \nu_1}{\partial p_1} \right| < \left| \frac{\partial \nu_2}{\partial p_1} \right|$*, or if* $\rho > \frac{\varpi_1}{\varpi_2}$ *and* $\left| L_1 \frac{\partial \nu_1}{\partial p_1} \right| > \left| \frac{\partial \nu_2}{\partial p_1} \right|$*. Otherwise, land allocated to crop1 only increases if the mean effect outweighs the risk effect.*

Proposition 3 thus shows that, being the expected mean effect positive, no diversification in favour of non-program crops is pursued if yields correlation is high and positive. However, if $\rho < 0$ an increase in L_1 requires an important reduction in the marginal variance of profit.

In order to assess the effects of decoupling on idle land, we now consider a model that studies the allocation of land among program crop production and set aside. In such a situation, the first order condition in (3) changes to (4) below:

$$\frac{\overline{\Pi}_1}{A} - RL_1\varpi_1^2 = 0 \tag{4}$$

Comparative statics allow to formulate the following two propositions:

PROPOSITION4. *Idle land is reduced with an increase in decoupled payments.*

This is due to the fact that an increase in decoupled payments reduces farmers' degree of risk aversion increasing their willingness to assume more risk. Given that idle land involves no risk, this alternative becomes less attractive in favour of producing agricultural commodities.

PROPOSITION5. *For a negative value of the mean effect of production, idle land increases with an increase in* p_1 *to the detriment of* L_1. *However, if the mean effect of production is positive, idle land only increases if the risk effect outweighs the mean effect.*

In a situation where the mean effect of production is positive, farmers have the incentive to increase the amount of land allocated to program crops to the detriment of idle land, as long as the increase in production risk discounted to a certainty equivalent does not outweigh the mean effect. However, if the mean effect is negative, an increase in p_1 reduces program crop land in favour of idle land.

In summary, our comparative statics analysis shows that decoupled payments have the effect of reducing idle land. In contrast, the reduction in program crop price supports can motivate land set aside. Decoupled payments can also stimulate a change in crop mix in favour of non-program commodities. This shift requires yields correlation to be negative or take low positive values. A decrease in program crop price supports can also boost non-program crops acreage under certain conditions. It is relevant to note that, with the exception of the influence of decoupled payments on idle land, the net effects of decoupling depend on issues such as yields correlation, changes in the variance of profit, or the magnitude of the mean and risk production effects. This impedes to anticipate the response to a decoupled program making it necessary to determine it empirically.

III. EMPIRICAL APPLICATION

As explained above, our empirical application is focused on the analysis of the effects of the US agricultural policy reforms in 1996 on land allocation decisions taken by a sample of Kansas farms. Specifically, we are interested in observing how the planting flexibility provisions and the decoupling of farm income support influenced Kansas farms' land use.

Farm-level data are taken from farm account records from the Kansas Farm Management Association database for the period 1998 to 2001. Retrospective data for these farms are also used to define some lagged variables used in the application.[4] The Kansas Farm Management Association database collects information from individual farms on an annual basis through a

[4] To be able to do so, a complete panel of data is built out of our sample.

cooperative record-sharing, farm management, and tax preparation arrangement. Around 2,500 full-time commercial holdings with gross sales exceeding $100,000 provide data to this database. Various farm types and areas in Kansas are represented in the dataset (Albright, 2001). The variables in the database include, among other information, farm financial and production data, balance sheet, cash flow and income statements. Our analysis is based on farm-level data, but aggregates are also used to define important variables that are unavailable in the farm-level dataset. These aggregates are taken from the United States Department of Agriculture (USDA) and the National Agricultural Statistics Service (NASS). USDA provided state-level PFC payment rates and NASS facilitated country-level price indices and state-level output prices and quantities.

Table 1 contains summary statistics for the variables used in the analysis. Following our model specification, we consider a variable input x that includes the application of herbicides and fertilizer, representing the main variable costs for the farms in the sample. Because input prices are not available from the Kansas database, we define w as a country-level input price index. An implicit quantity index for variable inputs is derived through the ratio of input use in currency units to the corresponding price index. The Kansas dataset does not provide information on the consumption of variable inputs by crop. We use Just et al. (1990) behavioural proposal to allocate variable input use among different crops.[5]

[5] We should note here that another allocation mechanism based on profit maximization was also used, but yielded inconsistent results. This is not surprising in light of Just et al. (1990) findings that the behavioural method is superior.

Two output categories are distinguished as quantity indices per acre (y_1 and y_2). Variable y_1 represents program crops and includes the production of wheat, corn, and grain sorghum per acre. Variable y_2 is the production of soybeans representing a non-program commodity. Together, wheat, corn, sorghum and soybeans represent the main crops in Kansas. Paasche indices for both crops are computed using state-level output prices and production to define p_1 and p_2.

A_i represents land allocated to alternative $i = 1, 2, 3$, being A the variable representing total crop acres, A_3 the acres left idle, and A_1 and A_2 the crop acres planted to program and non-program crops respectively. By using y_i, x_i, p_i, w, the value for $\overline{\Pi}_i$ can be determined. Computing quasi rents at the farm-level involves some problems. First, not every farm produces crop i [6] every year and when this happens $\overline{\Pi}_i$ cannot be determined at the farm-level. Second, the composition of y_1 can vary annually within a farm as the hectares planted to wheat, corn and sorghum change, which complicates the definition of a reasonable value for $\overline{\Pi}_1$ at the farm-level. In light of these problems, we define quasi rents using annual sample-means for the production and input consumption variables.[7]

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[6] The problem applies to crop $i = 2$.

[7] It is important to note here that other alternatives were also considered, including the use of farm-level $\overline{\Pi}_i$ values whenever possible (and averages otherwise), or the use of the Kansas Farm Management Association crop budgets (http://www.agmanager.info/crops/). However, these alternatives yielded results in contrast to widely accepted previous research results and thus were discarded.

Kansas database does not register PFC government payments. Instead, a single measure including all government payments received by each farm is available. To derive an estimate of farm-level PFC payments, the acreage of program crops (base acreage) and the base yield for each crop are approximated using farm-level data. The approximation uses the 1986-88 average acreage and yield for each program crop and farm. PFC payments per crop are derived by multiplying 0.85 by the base acreage, yield and the PFC payment rate. PFC payments per crop are then added to get total direct payments per farm.[8] A farm's initial wealth is defined as the farm's net worth.

IV. RESULTS

Table 1 shows that, during the period studied, more than 62% of crop land was planted to program crops, a 26% was devoted to non-program commodities, being the rest left idle. Sample means also show that estimated PFC payments represent around 1.8% of farmers' initial wealth. Of interest is the fact that, for the period of analysis, the expected profit per acre derived from non-program commodities outweighs the one obtained by planting program crops. Also, during the period of study, $\mathrm{var}(\Pi_2) > \mathrm{var}(\Pi_1)$, which involves higher income risk derived from non-program crops.[9] Two-stage nonlinear least squares parameter

[8] This estimate is compared to actual government payments received by each farm. If estimated PFC payments exceed actual payments, the first measure is replaced by the second.

[9] Differences in the variance of profits might partly reflect the fact that while y_1 is a composite output, y_2 represents a single crop.

estimates for the first-order conditions of the land allocation decision (see table 2) provide evidence that farmers in our sample are risk averse, and that the degree of risk aversion decreases with farmers' wealth, i.e., farmers exhibit DARA preferences. Price, cross-price and payment elasticities of the proportion of land planted to program and non-program crops or left idle are presented in table 3. As expected, results suggest that an increase in its own price will generate an increase in the quantity of land planted to program crops. Quite the opposite, the price elasticity of non-program crops is negative. This result is not surprising given the high income risk associated to y_2 during the period of analysis. An increase in p_2 does not only involve an increase in mean income, but also a substantial increase in income variance. This lays out the necessary conditions for a failure in the 'law of supply', that contends that the quantity supplied by price-taking producers will rise in response to an increase in output prices. An increase in profit risk above the increase in its mean will originate this failure. This result is in accord with the findings of Just and Zilberman (1986). Results indicate that cross-price effects are negative for program crop and positive for non-program crop prices. Hence, a decline in program crop market prices (p_1) as a result of a decrease in price supports, will motivate a change in land use away from program crops in favour of non-program commodities. In contrast, farmers will respond to an increase in non-program crop prices by increasing land devoted to other uses such as program crops. The response of idle land to changes to market prices is quite different depending on whether it is the program or the non-program crop price that is shocked. An increase in program crop prices creates a strong incentive to reduce idle land to plant program commodities.[10] This shift in land use takes place because the increase in mean income originated by the increase in p_1 outweighs the increase in income risk. However, an increase in p_2 does not reduce idle land. Instead idle acreage is increased. As noted before, the high risk associated to the production of y_2 for the period studied is increased with an increase in the output price. The relevance of the risk effect relative to the mean effect motivates farmers to set some land aside as a form of self-insurance. Land use is also sensitive to government subsidies. An increase in decoupled payments reduces farmers' degree of risk aversion and stimulates undertaking risky activities. This involves a reduction in idle land in favour of crop land planted to both program and non-program commodities.

Hence, our results show that agricultural policy decoupling is likely to have motivated a change in farmers' crop mix. The extremely low values of subsidy elasticities relative to price elasticities allow to predict a reduction in the acreage planted to program crops in favour of non-program commodities and idle land.

V. CONCLUDING REMARKS

This paper investigates the effects of decoupling on farmers' land allocation decisions and, specifically, on the crop mix and idle land. Coupled policies usually restrict farmers' capacity to respond to market conditions by imposing restrictive supply management rules. In this regard, decoupling involves

[10] High idle land elasticities are partly due to the low initial values of this variable.

increased planting flexibility and thus may motivate changes in land allocation. Other aspects of decoupling can also influence land allocation decisions. These aspects are the reduction in price supports for program crops and their replacement by lump sum transfers, which are likely to involve changes in relative market prices and in farmers' risk attitudes.

In order to show how these policy reforms could affect land use, we use an extended version of the Just and Zilberman (1986) model of production under uncertainty. Our model offers an improved picture of farmers' behaviour by allowing to optimize land allocation in response to policy and by considering land idling among land use alternatives. Theoretical results show that, under the assumption of DARA preferences, an increase in lump sum transfers will increase farmers' willingness to assume more risk. This could reduce the attractiveness of crop mix diversification away from program crops and in favour of non-program commodities as a strategy to manage farm income risk. This involves that this diversification will only be pursued if yields correlation between program and non-program crops is negative or takes low positive values, and if an increase in land allocated to program crops involves a substantial reduction in the profit variance. Under certain conditions of yields correlation, profit variance and mean income, a decrease in program crop price supports will motivate diversification away from these crops. Idle land will decrease as a result of a reduction in program crop prices, only if the mean effect of production is negative or if it is positive and the risk effect outweighs the mean effect. An increase in decoupled subsidies will motivate farmers to assume riskier enterprises and reduce uncultivated land.

We use farm-level data collected in Kansas to illustrate our model and determine the effects of the FAIR Act on crop mix diversification. Our results show that decoupling could have induced a change in farmers' crop mix by stimulating to reduce program crop acres in favour of non-program commodities and land idling.

APPENDIX

Proof of proposition 1. By totally differentiating equation (3), the following expression can be derived:

$$\frac{\partial L_1}{\partial G} = -\frac{1}{D}\frac{\partial R}{\partial \overline{W}}\left[L_1 v_1 + v_2\right] \tag{6}$$

where $D > 0$ is the negative value of the second order condition of the optimization problem. If crop yields are negatively correlated (i.e. $\rho < 0$), $v_2 < 0$, which involves that $\frac{\partial L_1}{\partial G} > 0$ if $\left|L_1 v_1\right| > \left|v_2\right|$. If the correlation coefficient is positive (i.e. $\rho > 0$), $v_2 > (<) 0$ if $\rho > (<) \frac{\varpi_2}{\varpi_1}$. We can thus conclude that if $0 < \rho < \frac{\varpi_2}{\varpi_1}$ and $\left|L_1 v_1\right| > (<) \left|v_2\right|$, then $\frac{\partial L_1}{\partial G} > (<) 0$. Otherwise, if $\rho > \frac{\varpi_2}{\varpi_1}$, land allocated to program crops will increase with an increase in decoupled payments $\left(\frac{\partial L_1}{\partial G} > 0\right)$.

Proof of proposition 2. By totally differentiating equation (3), the following expression can be derived:

$$\frac{\partial L_1}{\partial p_1} = \frac{\overline{y}_1}{D}\left[\frac{1}{A} - \varepsilon_{R\_\overline{W}}\frac{L_1\left(\overline{\Pi}_1 - \overline{\Pi}_2\right)}{\overline{W}}\right] - \frac{R}{D}\left[L_1\left(\frac{\partial v_1}{\partial p_1}\right) + \frac{\partial v_2}{\partial p_1}\right] \tag{7}$$

where $\bar{y}_1\left[\frac{1}{A}-\varepsilon_{R\_\bar{W}}\frac{L_1\left(\bar{\Pi}_1-\bar{\Pi}_2\right)}{\bar{W}}\right]$ represents the mean effect of production per unit of land, being $R\left[L_1\left(\frac{\partial v_1}{\partial p_1}\right)+\frac{\partial v_2}{\partial p_1}\right]$ the variance effect discounted to a certainty equivalent using the Arrow-Pratt coefficient of absolute risk aversion. Expression $\frac{\partial v_1}{\partial p_1}$ represents the marginal variance of the marginal profit, and $\frac{\partial v_2}{\partial p_1}$ stands for a half of the change in the marginal variance of profit when $L_1=0$. Elasticity $\varepsilon_{R\_\bar{W}}=\frac{\partial R}{\partial\bar{W}}\frac{\bar{W}}{R}<0$ represents the wealth elasticity of the Arrow-Pratt coefficient of absolute risk aversion.

If yields correlation coefficient is negative ($\rho<0$), then $\frac{\partial v_1}{\partial p_1}>0$ and $\frac{\partial v_2}{\partial p_1}<0$, i.e., the variance of the marginal profit increases, but the marginal variance of profit decreases. In such a situation, the sign of the marginal risk effect is positive if $\left|L_1\frac{\partial v_1}{\partial p_1}\right|>\left|\frac{\partial v_2}{\partial p_1}\right|$ which involves $\frac{\partial L_1}{\partial p_1}<0$. Otherwise, the marginal effect is negative and the sign of $\frac{\partial L_1}{\partial p_1}$ depends on the magnitude of the mean effect relative to the marginal effect. If yields correlation is positive, then $\frac{\partial v_1}{\partial p_1}>(<)0$ if $\rho<(>)\frac{\varpi_1}{\varpi_2}$ and $\frac{\partial v_2}{\partial p_1}>0$. This involves that if $\rho>\frac{\varpi_1}{\varpi_2}$ and $\left|L_1\frac{\partial v_1}{\partial p_1}\right|<\left|\frac{\partial v_2}{\partial p_1}\right|$, or if $0<\rho<\frac{\varpi_1}{\varpi_2}$, then $\frac{\partial L_1}{\partial p_1}<0$.

Proof of proposition 3. See proof of proposition 2.

Proof of proposition 4. By totally differentiating equation (4), the following expression can be derived:

$$\frac{\partial L_1}{\partial G} = -\frac{L_1 \varpi_1^2}{D}\frac{\partial R}{\partial \overline{W}} > 0 \tag{8}$$

Proof of proposition 5. By totally differentiating equation (4), the following expression can be derived:

$$\frac{dL_1}{dp_1} = \frac{\overline{y}_1}{D}\left[\frac{1}{A} - \varepsilon_R \frac{L_1 \overline{\Pi}_1}{\overline{W}}\right] - \frac{R}{D}\left[2L_1 p_1 \sigma_1^2\right] \tag{9}$$

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Table 1. *Summary statistics for the variables of interest*

Variable	Mean (Standard deviation) n= 2,241
y_1	106.54 (11.51)
y_2	118.74 (27.85)
x_1	39.32 (1.48)
x_2	28.17 (1.49)
p_1	1.01 (0.06)
p_2	0.91 (0.06)
w	1.02 (0.03)
$\bar{\Pi}_1$	67.55 (7.07)
$\bar{\Pi}_2$	79.61 (6.58)

Note: all monetary values are expressed in constant 1998 currency units

Table 1. *Summary statistics for the variables of interest*

Variable	Mean (Standard deviation) n= 2,241
$\mathrm{var}(\Pi_1)$	180.81
	(22.43)
$\mathrm{var}(\Pi_2)$	861.61
	(111.13)
$\mathrm{cov}(\Pi_1\Pi_2)$	268.39
	(18.76)
W_0	669,663.10
	(587,319.18)
G	12,014.92
	(9,233.03)
L_1	0.62
	(0.23)
L_2	0.26
	(0.24)
L_3	0.12
	(0.18)
A	1075.90
	(827.46)

Note: all monetary values are expressed in constant 1998 currency units

Table 2. *Parameter estimates and summary statistics for the coefficients of risk aversion*

Parameter	Mean predicted value (Standard deviation)
η	0.034** (0.007)
β	-0.353** (0.017)
F-test ($\eta = 0$ and $\beta = 0$)	23,603**

Note: Two asterisks (**) denote statistical significance at the α = 0.05 level

Table 3. *Elasticity estimates*

Elasticity	Mean value (Standard deviation)
$\varepsilon_{L_1\_p_1}$	1.9132** (0.1722)
$\varepsilon_{L_2\_p_1}$	-2.0844** (0.1217)
$\varepsilon_{L_3\_p_1}$	-5.5302** (0.6439)
$\varepsilon_{L_1\_p_2}$	0.1668** (0.0517)
$\varepsilon_{L_2\_p_2}$	-1.2794** (0.0816)
$\varepsilon_{L_3\_p_2}$	1.9433** (0.0934)
$\varepsilon_{L_1\_G}$	0.0064** (0.0003)
$\varepsilon_{L_2\_G}$	0.0055** (0.0003)
$\varepsilon_{L_3\_G}$	-0.0460** (0.0024)

Note: (**) denotes statistical significance at the $\alpha = 0.05$ level